Wind Turbines on CO2 Neutral Luminaries in Urban Areas

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ABSTRACT

In the present work, a simulation of three hybrid street luminaries (lamps) comprizing wind turbines is presented. The luminaries are: *Green Power* with a Savonius (left), *United Electricity* with a horizontal-axis (center), and *Sanya* with a helical H-rotor (right) turbines. The simulated luminaries are also equipped with photovoltaic panels, batteries and LEDs, detailed investigation of which is outside the scope of the present work.

Analysis of the turbines' performance based on producer-supplied power curves is presented together with an estimation of the wind climate in Copenhagen.

A new twisted Savonius rotor is proposed for a luminary being designed for Copenhagen within the "Development of CO2 neutral urban luminary" project.

OBJECTIVES

The objectives of the project are to investigate the potential of combining wind energy and solar energy to power a luminary and to design and construct a prototype. In the poster, especially the wind energy part of the concept is in focus. The basis of the design of the wind turbine is made by Mertens [1] and Beller [2].

METHODS: Assessment of wind climate

In order to simulate the luminaries as working in a Copenhagen district comprising 1-2 story single family buildings, time series of wind speed measured at a location 20 km north of Copenhagen was delivered by the Danish Meteorological Institute (www.dmi.dk). This was the closest available location from which a complete year-long time series was available. Then, this data was corrected to account for the specific urban landscape – building height and density – using the roughness step method described by Beller [2].

METHODS: Computational model of the luminary

The investigated turbines are actual components in luminaries manufactured by the aforementioned producers. Each of these turbines is of different size. However, in the present work, each swept area was scaled to be of 2 m^2 for a better comparison. Also the remaining parameters of the simulated luminaries were assumed to be identical.

In order to simulate the photovoltaic panel, illumination values representative to the considered district were supplied by Soda-Is. Simulation of the turbines was a simple table lookup based on the producer-supplied power curves presented below. Note that according to Mertens [3], producer-supplied power curves of small turbines are often poor indication of their actual performance. Therefore, the power curves will be verified experimentally in the next stage of the project.

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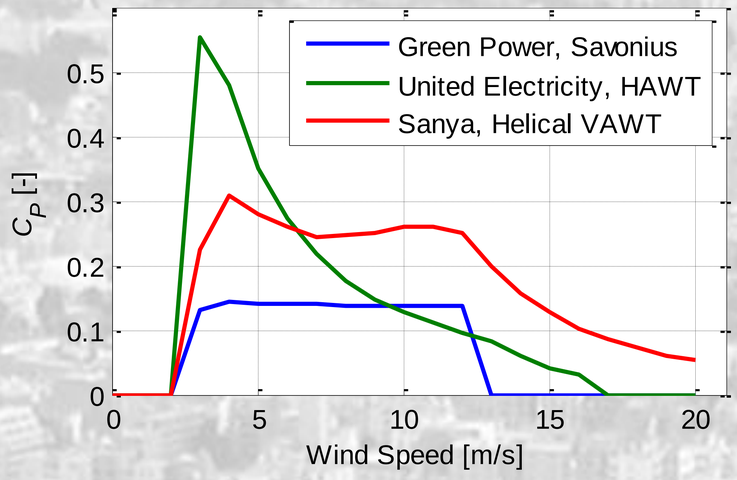
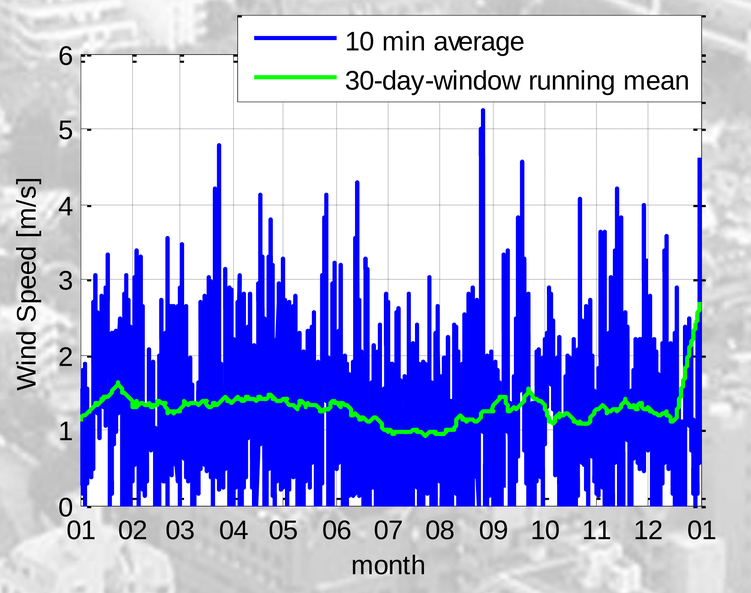


RESULTS: Assessment of wind climate

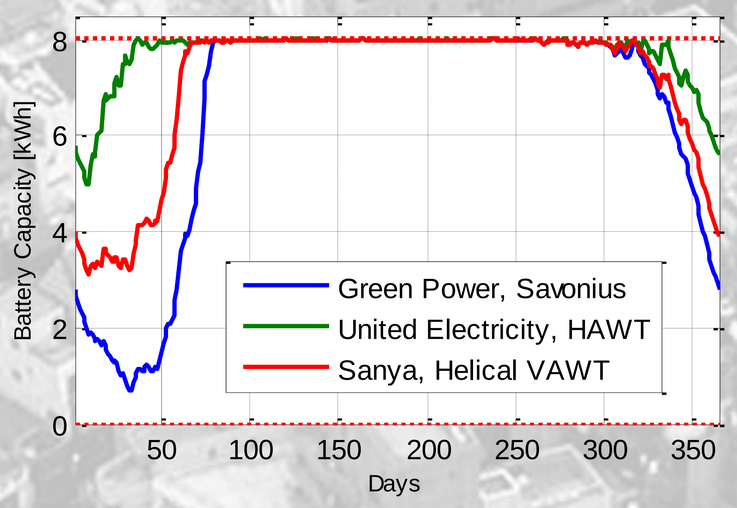
The analysis of the wind climate showed that the wind energy in the considered urban environment was relatively low. The time series of the wind speed used in the simulations is presented below together with the 30-day-window running mean:



The reference height at which the wind speed was calculated was 8 m as this was assumed to be the hub height for all three luminaries. 5.55 m being the sum of the displacement height and the roughness length was assumed to be the bottom of the logarithmic wind profile. This does not mean that the average wind speed below 5.55 m is zero. However, this wind speed was assumed to be relatively low and difficult to approximate with the available tools.

Results: Modelling the luminary

Work of the luminaries throughout one year was simulated. The figure below presents time series of the energy level in the batteries. If any of the curves touched the zero level, the simulated luminary would stop working. Here, the battery capacity was adjusted in order for none of the three curves to touch the zero level. The simulation was iterated until the start and end energy levels of each luminary were equal.

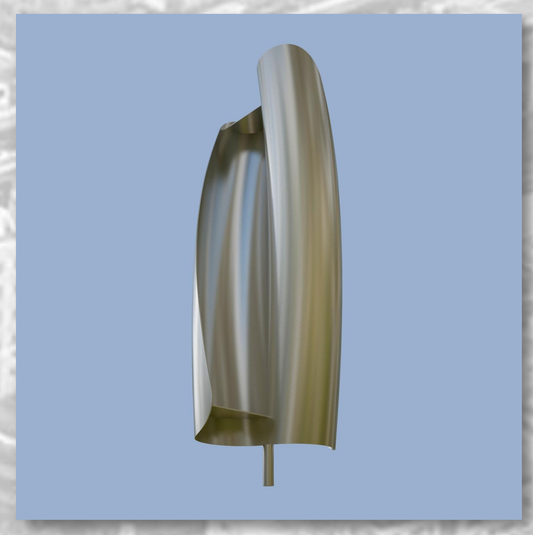


Otherwise, a simulation starting with the full battery and ending with a partly discharged battery would not be representative of real life, year after year. The simulations showed that January, February and December are associated with the highest risk of energy deficit.

CHOICE OF THE ROTOR

Although the results shown in the preceding section indicated that a horizontal axis turbine may be the best alternative to use on a hybrid luminary, the actual choice is more complex. The relatively high difference in performance should be verified by doing an experimental study of the actual power curves. The low average wind speed at which the turbines would need to operate points at a Savonius turbine, being known for its low starting torque. Another issue is that the tip speed of lift-driven concepts like the horizontal-axis turbine might run up to approximately 15 times the wind speed whereas the optimal tip speed of a Savonius rotor is approximately 0.7 of the wind speed. Thus, concerning safety and aesthetics, Savonius type is more attractive in urban areas. And finally, the rapidly changing wind direction in urban environment could cause the horizontal-axis turbine to flap, decreasing its efficiency due to yaw misalignment.

Taking all these factors into consideration, a decision was made to pursue a 90-degree-twist single-stage Savonius wind turbine with small-size end plates mounted and the top and bottom of the rotor, as presented below.



CONCLUSIONS

Simulation of the hybrid luminaries based on producer-supplied turbine power curves was presented together with an estimation of the wind climate in Copenhagen district comprising 1-2 story single family buildings. The analysis showed the need for balancing the size of the wind turbine, the photovoltaic panels, luminary and the battery the best way in order to avoid the winter energy deficit. A new 90-degree-twist single-stage Savonius wind turbine with small-size end plates mounted and the top and bottom of the rotor was proposed for a luminary being designed for such a district within the "Development of CO2 neutral urban luminary" project.

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